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N03/420/H(2)M+

# **MARKSCHEME**

**November 2003**

**CHEMISTRY**

**Higher Level**

**Paper 2**

1. Follow the markscheme provided, do **not** use decimals or fractions and mark only in **RED**.
2. Where a mark is awarded, a tick (✓) should be placed in the text at the **precise point** where it becomes clear that the candidate deserves the mark.
3. Sometimes, careful consideration is required to decide whether or not to award a mark. In these cases write a brief annotation in the **left hand margin** to explain your decision. You are encouraged to write comments where it helps clarity, especially for moderation and re-marking.
4. Unexplained symbols or personal codes/notations on their own are unacceptable.
5. Record subtotals (where applicable) in the right-hand margin against the part of the answer to which they refer (next to the mark allocation for Section A). Do **not** circle sub-totals. **Circle the total mark for the question in the right-hand margin opposite the last line of the answer.**
6. For Section B, show a mark for each part question (a), (b), *etc.*
7. Where an answer to a part question is worth no marks, put a zero in the right-hand margin.
8. Section A: Add together the total for each question and write it in the Examiner column on the cover sheet.  
Section B: Insert the total for each question in the Examiner column on the cover sheet.  
Total: Add up the marks awarded and enter this in the box marked TOTAL in the Examiner column.
9. After entering the marks on the cover sheet, check your addition to ensure that you have not made an error. Check also that you have transferred the marks correctly to the cover sheet. **We have script checking and a note of all clerical errors may be given in feedback to examiners.**
10. Every page and every question must have an indication that you have marked it. Do this by **writing your initials** on each page where you have made no other mark.
11. If a candidate has attempted more than the prescribed number of questions, mark only the required number of answers in the order in which they are presented in the script, **unless the candidate has indicated the questions to be marked on the cover sheet**. Make a comment to this effect in the left hand margin.
12. A candidate can be penalized if he/she clearly contradicts him/herself within an answer. Make a comment to this effect in the left hand margin.

## Subject Details:      Chemistry HL Paper 2 Markscheme

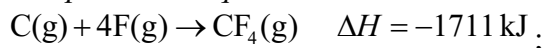
### General

- Each marking point is usually shown on a separate line or lines.
- Alternative answers are separated by a slash (/) – this means that either answer is acceptable.
- Words underlined are essential for the mark.
- Material in brackets ( ... ) is not needed for the mark.
- The order in which candidates score marks does not matter (unless stated otherwise).
- The use of **OWTTE** in a markscheme (the abbreviation for “or words to that effect”) means that if a candidate’s answer contains words different to those in the markscheme, but which can be interpreted as having the same meaning, then the mark should be awarded.
- Please remember that many candidates are writing in a second language, and that effective communication is more important than grammatical accuracy.
- In some cases there may be more acceptable ways of scoring marks than the total mark for the question part. In these cases, tick each correct point, and if the total number of ticks is greater than the maximum possible total then write the maximum total followed by **MAX**.
- In some questions an answer to a question part has to be used in later parts. If an error is made in the first part then it should be penalized. However, if the incorrect answer is used correctly in later parts then “follow through” marks can be scored. Show this by writing **ECF** (error carried forward). This situation often occurs in calculations but may do so in other questions.
- Units for quantities should always be given where appropriate. In some cases a mark is available in the markscheme for writing the correct unit. In other cases the markscheme may state that units are to be ignored. Where this is not the case, penalize the omission of units, or the use of incorrect units, once only in the paper, and show this by writing **–1(U)** at the first point at which it occurs.
- Do not penalize candidates for using too many significant figures in answers to calculations, unless the question specifically states the number of significant figures required. If a candidate gives an answer to fewer significant figures than the answer shown in the markscheme, penalize this once only in the paper, and show this by writing **–1(SF)** at the first point at which this occurs.
- If a question specifically asks for the name of a substance, do not award a mark for a correct formula; similarly, if the formula is specifically asked for, do not award a mark for a correct name.
- If a question asks for an equation for a reaction, a balanced symbol equation is usually expected. Do not award a mark for a word equation or an unbalanced equation unless the question specifically asks for this. In some cases, where more complicated equations are to be written, more than one mark may be available for an equation – in these cases follow the instructions in the mark scheme.
- Ignore missing or incorrect state symbols in an equation unless these are specifically asked for in the question.
- Mark positively. Give candidates credit for what they have got correct, rather than penalizing them for what they have got wrong.
- If candidates answer a question correctly, but by using a method different from that shown in the markscheme, then award marks; if in doubt consult your Team Leader

# SECTION A

1. (a)  $\text{C(s)} + 2\text{F}_2\text{(g)} \rightarrow \text{CF}_4\text{(g)} \quad \Delta H_1 = -680 \text{ kJ};$   
 $4\text{F(g)} \rightarrow 2\text{F}_2\text{(g)} \quad \Delta H_2 = 2(-158) \text{ kJ};$   
 $\text{C(g)} \rightarrow \text{C(s)} \quad \Delta H_3 = -715 \text{ kJ}$

Accept reverse equations with  $+\Delta H$  values.



[4]

$$\text{average bond enthalpy} = \frac{-1711}{4} = -428 \text{ kJ mol}^{-1};$$

Accept + or – sign.

Units not needed for mark, but deduct [1] if incorrect units.

No significant figures penalty.

For a correct enthalpy cycle with symbols, award [2].

For correct numerical value (1711), award [1].

For incorrect value, award [0].

For correct average bond enthalpy, award [1] (ECF).

It is possible to score [3] for an incorrect answer.

- (b) (i)  $(\Delta G^\ominus = \Delta H^\ominus - T \Delta S^\ominus)$   
 as  $T$  increases,  $-T \Delta S^\ominus$  becomes larger / more positive;  
 $\Delta G$  increases / becomes more positive / less negative;  
 process becomes less spontaneous / reverse reaction favoured;

[3]

- (ii)  $(\Delta G^\ominus = \Delta H^\ominus - T \Delta S^\ominus = 0)$

$$\text{therefore, } T = \frac{\Delta H}{\Delta S} = \frac{-9830 \text{ J mol}^{-1}}{-35.2 \text{ J K}^{-1} \text{ mol}^{-1}};$$

$$= 279 \text{ K} = 6^\circ \text{C};$$

(no SF penalty) ECF

(ECF if kJ used above)

temperature at which solid and liquid are in equilibrium with each other /  
 melting point / freezing point / T at which it changes from spontaneous to  
 non-spontaneous or vice-versa / T at which no (useful) work is done;

[3]

2. (a)  $3\text{Ag}^+(\text{aq}) + \text{XO}_4^{3-}(\text{aq}) \rightarrow \text{Ag}_3\text{XO}_4(\text{s});$  [2]  
 [1] for balanced equation and [1] for states.

(b) (i)  $n_{\text{Ag}^+} = cV = 0.2040 \text{ mol dm}^{-3} \times 0.04118 \text{ dm}^3$   
 $= 0.008401 / 8.401 \times 10^{-3} \text{ mol}$  (–1 SF)  
 Unit not needed for mark. [1]

(ii)  $n_{\text{Ag}_3\text{XO}_4} = \frac{1}{3} n_{\text{Ag}^+} = \frac{1}{3} \times 0.008401 \text{ mol}$  [1]  
 $= 0.002800 / 2.800 \times 10^{-3} \text{ mol}$   
 ECF from (a) / (b) (i).

(iii) 0.002800 mol weighs 1.172 g  
 1 mol weighs  $\frac{1.172 \text{ g}}{0.002800 \text{ mol}} = 418.6 \text{ g mol}^{-1}$  [2]  
 Accept answer in range 418 to 419.  
 No penalty for too many sig figs.  
 ECF from (b)(ii) ( $\text{g mol}^{-1}$ );  
 Do not accept g.

(iv)  $(3 \times 107.87) + x + 4(16.0) = 418.6$  (ECF)  
 therefore,  $x = 30.99$  (accept 31.0 / 31); [2]  
 P / phosphorus;

3. (a) mass / density / for gases: rate of effusion or diffusion / melting point / boiling point [1]

*Do not accept mass number.*

- (b) if  $^{35}\text{Cl} = x$ , then  $(x \times 35.00) + (1 - x) 37.00 = 35.45$ ;

*Award [1] for set up.*

therefore,  $x = 0.775$

[2]

$^{35}\text{Cl} = 77.5\%$  and  $^{37}\text{Cl} = 22.5\%$  (need both for mark);

- (c) Br:  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^5$  /  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^5$ ;

*For Br, accept only complete configuration (which is asked for).*

$\text{Fe}^{3+}$ :  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$ ;

[2]

*Accept [Ar]  $3d^5$  since [Ar] already listed above.*

4. (a) (i)  $\text{p}K_a = 3.75$ , therefore  $K_a = 1.78 \times 10^{-4}$  (accept  $1.8 \times 10^{-4}$ ) [1]

*No units required.*

- (ii) weak acid;

less  $[\text{H}^+]$  / partial dissociation / more reactants / less products /

[2]

$K_a \ll 1$  / small  $K_a$ ;

- (iii)  $(\text{HCOOH}(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{HCOO}^-(\text{aq}))$

$$K_a = \frac{[\text{H}^+][\text{HCOO}^-]}{[\text{HCOOH}]} = \frac{x^2}{0.010};$$

$$(x^2 = 1.78 \times 10^{-6})$$

$$x = 1.33 \times 10^{-3} \text{ mol dm}^{-3} = [\text{H}^+] \text{ (no mark without units);}$$

*ECF from (a) (i).*

[4]

*No penalty for incorrect significant figures.*

$$\text{pH} = 2.88 / 2.9 \text{ (ECF);}$$

assume  $x \ll 0.010$  /  $25^\circ\text{C}$  / negligible dissociation;

- (b) add strong base / sodium hydroxide or other named alkali / salt of methanoic acid /  $\text{HCOONa}$  to methanoic acid;

in equimolar amounts / quantities / so that  $[\text{HCOOH}] = [\text{HCOO}^-]$ ;

(from  $K_a$  expression)  $\text{pH} = \text{p}K_a (= 3.75)$ ;

[3]

5. (a) (i) oxidation half-reaction:  $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$ ;  
 reduction half-reaction:  $2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2 + 2\text{OH}^-$  /  $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$ ;  
*Award [1] only if equations are interchanged.* [2]  
*States not required.*

- (ii) Na has high  $E_{\text{red}}^\ominus$  /  $\text{Na}^+$  not readily reduced (in comparison to  $\text{H}_2\text{O}$ ) / if  
 formed, Na would (immediately) react with water to form  $\text{Na}^+$  [1]

- (b)  $\text{H}_2(\text{g})$  and  $\text{O}_2(\text{g})$  / *accept names*;  
 $2\text{H}_2\text{O} \rightarrow \text{O}_2 + 4\text{H}^+ + 4\text{e}^-$  /  $4\text{OH}^- \rightarrow 2\text{H}_2\text{O} + \text{O}_2 + 4\text{e}^-$ ;  
 water is oxidized (instead of the halide);  
 since  $E_{\text{ox}}^\ominus$  for  $\text{F}^-$  is very negative /  $E_{\text{red}}^\ominus$  for  $\text{F}_2$  is very high;  
*Accept answer based on oxidizing / reducing strengths.* [4]

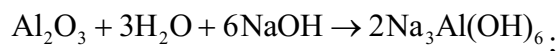
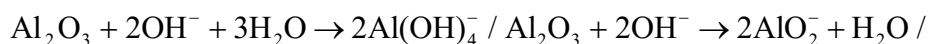
## SECTION B

6. (a) oxides of: Na, Mg: basic;  
Al: amphoteric;  
Si to Cl: acidic;  
Ar: no oxide;

*All four correct: [2], two or three correct [1].*

basic oxide:  $\text{Al}_2\text{O}_3 + 6\text{H}^+ \rightarrow 2\text{Al}^{3+} + 3\text{H}_2\text{O}$  /  $\text{Al}_2\text{O}_3 + 6\text{HCl} \rightarrow 2\text{AlCl}_3 + 3\text{H}_2\text{O}$ ;

acidic oxide:



[4]

- (b) (i) Mg:  $3s^2$  and Al:  $3s^2 3p^1$  (*need both for mark*);  
3p electron is higher in energy than 3s (and easier to remove);

[2]

- (ii)  $\text{V}^{3+}$ :  $[\text{Ar}] 3d^3$  and  $\text{Zn}^{2+}$ :  $[\text{Ar}] 3d^{10}$  (*need both for mark*);  
colour due to **splitting of partially filled d orbitals** (at different energy levels);  
electronic transitions between these are responsible for colour;  
 $\text{V}^{3+}$  has partially filled d orbitals /  $\text{Zn}^{2+}$  does not;  
 $\text{V}^{3+}$  not in its highest oxidation state (and can be oxidized);  
 $\text{Zn}^{2+}$  in its highest oxidation state (and cannot be further oxidized);

[6]

- (c) (i) 1<sup>st</sup> IE of K < Na as valence electron of K is further away / valence electron of K in  $n = 4$ , valence electron of Na in  $n = 3$ ;  
1<sup>st</sup> IE of K **much less** than that of Ar;  
since Ar (also  $n = 3$ ) has greater nuclear charge (compared to Na);

[3]

- (ii) valence electrons in the **same** main energy level;  
Mg has greater nuclear charge / Mg: 12 protons, Na: 11 protons;  
electrons pulled closer together in Mg / smaller radius;  
Mg has higher ionization energy;

[4]

- (iii) second electron in Na removed from  $n = 2$ , whereas for Mg second electron is removed from  $n = 3$ ;  
therefore, easier to remove in Mg and lower 2<sup>nd</sup> IE for Mg / harder to remove in Na and higher 2<sup>nd</sup> IE for Na;

[2]

- (d) ligand: a molecule or ion that can bond to a (central) metal ion (to form a complex);

$\text{NH}_3$ : Lewis base and  $\text{Cu}^{2+}$ : Lewis acid (*need both for mark*);

each  $\text{NH}_3$  / ligand donates an electron pair (to  $\text{Cu}^{2+}$ );

forming coordinate covalent / dative covalent bond;

[4]

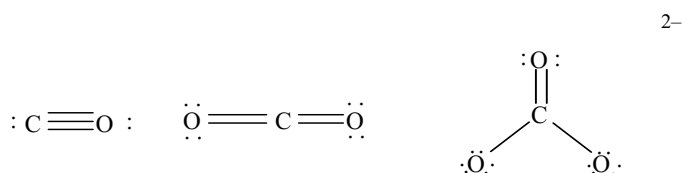


7. (a) for  $\text{H}_2\text{S}$ ,  $\text{H}_2\text{Se}$  and  $\text{H}_2\text{Te}$ , as size / mass /  $M_r$  increases, van der Waal's forces increase (and b pt. increases);  
 $\text{H}_2\text{O}$  experiences H-bonding ; [3]  
 H-bonding stronger than van der Waals' / explanation of H-bonding;

- (b) (i)  $\text{C}_4\text{H}_{10}$  : non-polar, only van der Waal's forces that cannot replace / interact with H-bonding in water; [2]  
 $\text{C}_2\text{H}_5\text{Cl}$  : only slightly polar / not capable of H-bonding with water;

- (ii)  $(\text{CH}_3)_2\text{CO}$  : highly polar / forms H-bonding with water; [2]  
 $\text{C}_3\text{H}_7\text{OH}$  : forms H-bonding with water (as H is bonded to O);

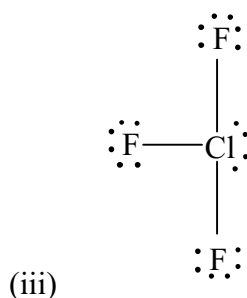
- (c) (i)
- 



OTTWE

*Award [1] each. Need charge on  $\text{CO}_3^{2-}$  for [1].  
 Penalize missing lone electron pairs only once.* [3]

- (ii)  $\text{CO}_3^{2-}$  ;  
 bond order  $1\frac{1}{3} / 1\frac{1}{3}$  bonds each compared to double bonds in  $\text{CO}_2$  and triple bond in CO;  
 the fewer the number of bonding electrons, the less tightly nuclei are held together, the longer the bond; [3]



No mark if lone  $e^-$  pairs on F or Cl are missing.

No mark if lone  $e^-$  pairs on F or Cl are missing.

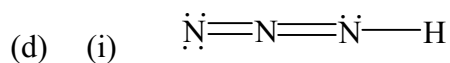
(3 bonded, 2 lone  $e^-$  pairs) planar / T-shaped;

[2]

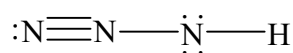
Accept drawing with T-shape.

Award [1] for correct structure and [1] for the shape.

Accept alternative answer using  $\text{ClF}_3$



I



[2]

II

- (ii)  $\text{N}-\text{N}-\text{N}$   $180^\circ$  in both;  
due to two centres of electron charge / density (arranged as far apart as possible);

I:  $\text{N}-\text{N}-\text{H} \approx 120^\circ / = 120^\circ$ ;  
due to three centres of electron charge / three electron pairs (one of which is a lone  $e^-$  pair);

II:  $\text{N}-\text{N}-\text{H} \approx 109^\circ / < 109^\circ$  / any angle between  $104^\circ$  and  $109^\circ$ ;  
four electron pairs / four centres of electron charge, two of which are lone  $e^-$  pairs /  
extra repulsion due to lone electron pairs;

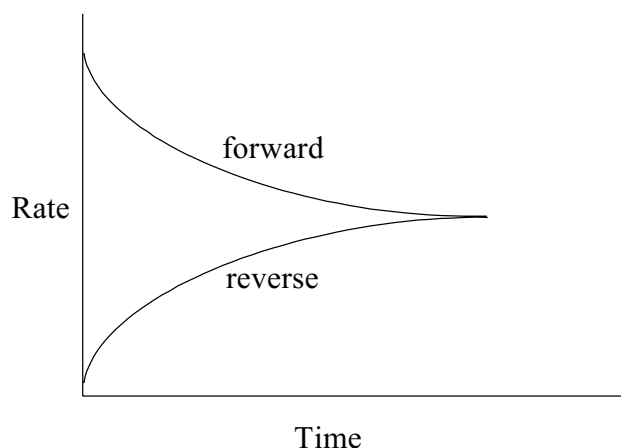
[6]

(iii) I:  $\text{sp}^2$ ;

II:  $\text{sp}^3$ ;

[2]

8. (a) (i)  $[\text{NO}]$  constant,  $[\text{O}_2]$  doubles, rate doubles;  
 $\text{rate} \propto [\text{O}_2]$  / first order;  
 $[\text{NO}]$  doubles,  $[\text{O}_2]$  doubles, rate increases 8 times;  
 $\text{rate} \propto [\text{NO}]^2$  / second order;  
 $\text{rate} = k [\text{NO}]^2 [\text{O}_2]$  /  $\text{rate} \propto [\text{NO}]^2 [\text{O}_2]$ ; [5]
- (ii) slow step / rate determining step involves only one NO and one  $\text{O}_2$ ; [2]  
 not two NO and one  $\text{O}_2$  (as required by rate-expression);
- (iii) since two NO and one  $\text{O}_2$  involved in the (one step) mechanism, correct rate expression possible; [2]  
 but unlikely that three particles will collide at the same time;
- (iv) from fast step  $[\text{NO}_3]$  depends on  $[\text{NO}]$  and  $[\text{O}_2]$ ;  
 rate depends on  $[\text{NO}_3]$  and  $[\text{NO}]$ ;  
 thus rate must depend on  $[\text{NO}]^2 [\text{O}_2]$  (consistent with rate expression); [3]
- (v)  $\text{NO}(\text{g}) + \text{NO}(\text{g}) \rightarrow \text{N}_2\text{O}_2(\text{g})$  fast;  
 $\text{N}_2\text{O}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}_2(\text{g})$  slow;  
 similar reasoning to above / rate depends on  $[\text{N}_2\text{O}_2]$  and  $[\text{O}_2]$ , and [3]  
 $[\text{N}_2\text{O}_2]$  depends on  $[\text{NO}]$  and  $[\text{NO}]$  (thus consistent with the overall third order reaction);  
 Accept ECF from (ii) to (v).



- (b) two curves - one labeled "forward" starting up high up y-axis and one labeled "reverse" starting from zero;  
curves merge and become horizontal;  
No penalty for failing to label axes.

*forward reaction:*

highest concentration, thus rate high to begin with;  
as reaction proceeds, concentrations decrease, so does rate;

*reverse reaction:*

zero rate initially / at  $t = 0$  (since no products present);  
rate increases as concentration of products increases;

equilibrium established when rate of forward reaction = rate of reverse reaction;

[7]

- (c) (reaction is) endothermic;  
 $K_c$  increases with (increasing) temperature;  
forward reaction favoured / heat used up / OWTTE;

[3]

9. (a) (i) one general formula / same general formula;  
differ by  $\text{CH}_2$ ;  
similar chemical properties;  
gradual change in physical properties;  
*Award [1] for any two from last three.*

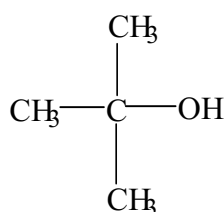
*functional group*: atom or group of atoms responsible for the characteristic reactions of the molecule / homologous series; [3]

- (ii) ethanol lower / ethanoic acid higher;  
due to larger mass of ethanoic acid / stronger intermolecular forces /  
stronger van der Waals' forces / stronger hydrogen bonding; [2]  
*No mark for H-bonding.*

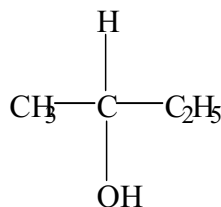
(iii)



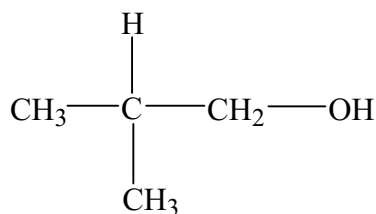
I



II



III



IV

*Four correct [2], two or three correct [1].*

structure III;  
has four different groups around central C / exists as two enantiomers that  
can rotate plane of polarized light in (opposite directions) / chiral centre /  
asymmetric carbon atom / asymmetric molecule; [4]

